# Appendix 7D

***Surface-Water Spill Modeling for the Longhorn Partners Pipeline,***
**Prepared by R.J. Brandes Company**

*TECHNICAL MEMORANDUM*

# *SURFACE-WATER SPILL MODELING FOR THE LONGHORN PARTNERS PIPELINE*

***prepared for:***
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***July 1999***

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# 1.0 EXECUTIVE SUMMARY

The Longhorn Partners Pipeline System traverses Texas from Houston to El Paso. The pipeline, which is currently unused, was formerly used for transmission of crude oil and is now proposed to carry refined petroleum products such as gasoline. The pipeline crosses several major streams within the Colorado River Basin. Concern has been raised regarding the potential for a leak or rupture and the resulting impacts to surface waters from contamination with refined products such as gasoline, which contains the toxic compound benzene, and also gasoline containing the additive MTBE (methyl tertiary-butyl ether). MTBE is relatively non-toxic, but it can have significant impact on drinking water because of undesirable taste and odor at very low concentrations.

The U.S. Army Corps of Engineers Riverine Emergency Management Model (REMM) was applied to the Longhorn Pipeline System at major stream crossings within the Colorado River Basin to determine potential impacts from spills of petroleum products. REMM is a one-dimensional model that uses river, chemical, and geographic information data to compute the time of travel and the fate of a chemical spill on a river system under various flow conditions. The program computes travel times and chemical concentrations from a spill as it travels downstream. It also computes concentration vs. time at any specific downstream location.

A goal of the modeling was to determine the impact of spills of various sizes in the streams of interest at low, average, and flood flow conditions. The Colorado River and Onion Creek were modeled directly using REMM. Impacts were estimated to nine other streams using a regression equation developed from the results of the Colorado River model. Pollutants modeled were benzene and MTBE in gasoline, and benzene in crude oil. Three pipeline spill scenarios were evaluated for this study. These were small, medium, and large spills of 50, 500, and up to 5000 barrels (bbl), respectively. The maximum possible spill at the Colorado River crossing was determined to be 2000 bbl, so that value was used at both that location and the other streams that were evaluated using

the Colorado model data. Conservative values were selected for model inputs where possible.

The primary conclusions of the study are as follows:

- Significant impacts (benzene concentrations >5 ppb or MTBE concentrations >20 ppb) to the Colorado River would likely occur for more than 100 miles downstream of the spill, except at low flow.

- Under low flow, significant impacts to the Colorado River would occur for 25 – 33 miles downstream.

- The duration of impacts (time for complete plume passage) at a downstream location is primarily dependent on flow and distance downstream. At Columbus, 92 miles downstream of the Colorado River crossing, the leading edge of the plume would arrive roughly 100 hours following a spill at average flows, and the trailing edge would pass after approximately 15 – 20 hours.

- Significant impacts to Onion Creek are projected to occur all the way to the mouth, or 26 miles from the modeled spill location, under all flow and spill conditions. Model results at very low flows may not be accurate, and actual impacts may not be as far as projected under those conditions.

- Impacts to other streams are estimated to be from approximately 20 to over 100 miles, with longer distances associated with larger spill volumes and higher flows. These are rough estimates made using a regression relationship based on the Colorado River model results.

- Impacts from a similar-sized crude oil spill would be over a greater distance than a gasoline spill, primarily because of the lower volatility of crude oil.

# 2.0 INTRODUCTION

The Longhorn Partners Pipeline System traverses Texas from Houston to El Paso. The pipeline, which is currently unused, was formerly used for transmission of crude oil and is now proposed to carry refined petroleum products such as gasoline. In the event of a spill or rupture of the pipeline at a stream crossing, impacts would be expected to occur for some distance downstream of the spill. A mathematical model, the U.S. Army Corps of Engineers Riverine Emergency Management Model (REMM), was applied to the Longhorn Pipeline System at major stream crossings within the Colorado River Basin to determine potential impacts from spills of petroleum products.

This Technical Memorandum is intended to supplement the Environmental Assessment (EA) for the Longhorn Partners Pipeline (LPP) System. Whereas this memorandum can be read as a stand-alone document, the EA should be referred to for details of the pipeline system and its proposed operation.

## 2.1 Purpose

The purpose of this Technical Memorandum is to document computer modeling studies designed to determine the impacts of a potential spill from the Longhorn Pipeline System to the Colorado River and its tributaries. The procedure followed in performing these studies was as follows: 1) select two streams for modeling, 2) select an appropriate public domain model capable of simulating a gasoline or crude oil spill to a stream, 3) obtain the input data required to run the model (hydraulic and hydrologic data for the streams, and chemical and physical data for the products that could be spilled), 4) execute the models under various conditions, and 5) perform a statistical analysis of the model output data and extend the results to other streams of interest in the Colorado Basin.

The two streams modeled for this study were the Colorado River and Onion Creek. Models were established beginning at approximately the point at which the

pipeline crosses each stream. The reach of the Colorado River modeled was from the existing pipeline crossing at river mile 227 between Bastrop and Smithville, to river mile 109 in the vicinity of Eagle Lake, a total distance of 118 miles. The reach of Onion Creek modeled was from the Travis-Hays county line, the approximate location of the crossing of the Austin Avoidance/Minimization Route Alternative, to the mouth of the creek at its confluence with the Colorado River, a total distance of 25.5 miles. This location was chosen rather than the existing pipeline crossing because the existing crossing would only yield a modeled distance of 16.5 miles. The longer distance gave more data for assessing impacts.

## 2.2 Report Organization

Following this introduction, Section 3 describes the model selected for this analysis, the REMM model. Sections 4 and 5 present the model inputs and results, respectively. Section 6 presents the results of the statistical analysis of the results and extension to other streams, Section 7 contains the conclusions, and Section 8 contains references used.

# 3.0 REMM MODEL

Following a review of existing models and other literature, the U.S. Army Corps of Engineers Riverine Emergency Management Model, or REMM, was selected for this analysis. REMM is a public domain model, the latest version of which (ver. 3.02) was released in December 1998. REMM is a one-dimensional model that uses river, chemical, and geographic information data to compute the time of travel and the fate of a chemical spill on a river system under various flow conditions. The program computes travel times and chemical concentrations from a spill as it travels downstream. It also computes concentration vs. time at any specific downstream location.

Pollutant behavior and fate in a stream depends on hydraulic and hydrologic conditions as well as chemical properties. The model requires hydraulic and hydrologic data, primarily in the form of stage-discharge-velocity relationships. Locations where such data are available are typically U.S. Geological Survey (USGS) gaging stations. The model also requires river cross-section data, dispersion coefficients and other in-situ river parameters, weather conditions, and properties of the spilled contaminants.

REMM contains property and fate data for gasoline and crude oil, as well as numerous specific chemical compounds. The specific compounds of interest to this study are benzene and methyl tertiary-butyl ether (MTBE). REMM contains data on benzene, but not MTBE. The required data for MTBE were obtained from other sources and added to the model for this study.

The water quality portion of REMM is based on several assumptions. The most important of these assumptions are as follows:

- Pollutants instantaneously mix in the water column.
- Water column is completely mixed.
- Degradation processes are first-order reactions.

- Interactions with the bottom sediments do not occur.
- Longitudinal dispersion of floating substances is effectively modeled by dissolved substances.
- Wind dispersion and shoreline effects are not considered, although wind impact on evaporation is considered.

The model is most effective with substances that have specific gravities (S.G.) less than or equal to 1.0 (light liquids). Dense liquids (S.G. >1.0) are poorly modeled because they tend to sink, have reduced evaporative losses, and interact with the bottom sediments. No dense liquids were modeled in this study.

For specific chemicals, algorithms using first-order degradation rate constants account for the fate processes of volatilization and hydrolysis. Sorption onto suspended sediments is accounted for by reducing the amount of chemical available to dissolve in the water column. Biodegradation, bioaccumulation, and direct photolysis are not accounted for, primarily because they are significantly slower than other processes. For gasoline and crude oil, the fate processes and partitioning for the large number of compounds involved is very complex. For modeling purposes, a conservative approach is taken in REMM by using an evaporation factor to simulate overall losses.

# 4.0 MODEL INPUTS

The REMM model requires three primary types of input data: 1) contaminant properties, 2) hydraulic and hydrology data for the stream being modeled, and 3) spill characteristics.

## 4.1 Properties of the Possible Contaminants

Gasoline containing up to 4.9% benzene and 15% MTBE could be transmitted by the pipeline. These are the primary substances evaluated in the modeling. In addition, the no action alternative considers resumption of crude oil transmission, so crude oil was also evaluated in the modeling, but to a lesser degree. Crude oil contains considerably less benzene than gasoline (0.14%) and does not contain MTBE. Under normal conditions of standard temperature and pressure, gasoline, benzene, and MTBE are liquids that are basically immiscible with water, although MTBE is considered partially soluble. When the gasoline mixture comes into contact with water, some fraction of the constituents can dissolve in the water. It should be understood that the solubility of individual gasoline constituents in a mixture is less than the solubility of the pure substance in water (Larkin and Kent, 1990). However, as a conservative assumption, it was assumed that all benzene and MTBE contained in the gasoline would be potentially dissolved in the water.

The U. S. EPA Maximum Contaminant Level (MCL) of benzene in water is 0.005 mg/L, or 5 parts per billion (ppb). Benzene is a known human carcinogen. MTBE is relatively non-toxic. There is no MCL for MTBE, but EPA has set a drinking water advisory level of 0.02 to 0.04 mg/L (20 to 40 ppb). It is considered undesirable in drinking water because of its impact on taste and odor and because it has a low biodegradation potential. Properties of the substances of interest as used in the modeling are shown in Table 4-1.

## Table 4-1. Properties of Contaminants (at 20° C)

| Property | Gasoline | Benzene | MTBE |
|---|---|---|---|
| Percent in Gasoline | 100 | 4.9 | 15 |
| Percent in Crude Oil | 0 | 0.14 | 0 |
| Molecular Weight | 119.38 | 78.11 | 88.15 |
| Specific Gravity | 0.735 | 0.879 | 0.74 |
| Solubility, mg/L | 8000 | 1780 | 48,000 |
| Octanol-Water Partition Coefficient | 93 | 135 | 17 |
| Henry's Law Constant, atm-$m^3$/mol | 0.0029 | 0.0055 | 0.00056 |
| Vapor Pressure, mm Hg | 160 | 76 | 240 |
| Drinking Water Standard, ppb | N/A | 0.005 | 0.020 |
| Boiling Point, °C | N/A | 80.1 | 55 |
| Melting Point, °C | N/A | 5.5 | -110 |

Source: REMM Technical Manual; Gustafson et al, 1996; Chemtrec, 1991

The properties of gasoline and benzene are relatively similar. On the other hand, MTBE is much more soluble in water, it will partition into the water phase more readily (low octanol-water partition coefficient), and it is not as easily volatilized from the dissolved phase (low Henry's Law constant). Because of these differences, MTBE was modeled as a separate pure chemical spill, whereas benzene was modeled as a percentage of a gasoline spill. It would be desirable to model all contaminants as a percentage of gasoline since that is the way they would be introduced to the water. However, it was assumed that benzene and gasoline would be removed at relatively the same rate, but MTBE would be removed at a slower rate. This approach is conservative, because it

probably underestimates the actual removal rate of MTBE, since some of it would likely be evaporated with the gasoline rather than partitioning into the water.

## 4.2 Hydraulics and Hydrology

A goal of the modeling was to determine the impact of spills of various sizes in the streams of interest at low, average, and flood flow conditions. The flows selected for these conditions were the 7-day, 2-year low flow (7Q2); the mean or median annual flow; and a flood flow that exceeds roughly 25 percent of the annual flood peaks. Based on an analysis of flow data from USGS gaging stations 08159200 – Colorado River at Bastrop, and 08159000 – Onion Creek at Hwy. 183 (USGS, 1998) and information from the Texas Natural Resource Conservation Commission (TNRCC, 1997), the flows selected for the two models are as follows:

- Colorado River
  - 7Q2 = 200 cubic feet per second (cfs)
  - Median = 1600 cfs
  - Flood = 10,000 cfs
- Onion Creek
  - 7Q2 = 0.6 cfs
  - Median = 6.3 cfs
  - Mean = 80 cfs
  - Flood = 2500 cfs

Cross-sections for the Colorado River were obtained at each of the USGS gaging stations, with a few supplementary sections obtained from the Lower Colorado River Authority (Mosier and Ray, 1992). These were supplemented as needed with data from USGS 7.5-minute topographic maps and detailed topographic maps of Bastrop County obtained from LCRA. Stage-discharge-velocity rating curves were obtained from the same sources. Flood flow stage and velocity were estimated at the LCRA sections, where

actual measurement data were not available. Manning's n for the channel was estimated at 0.030.

Data for Onion Creek were obtained primarily from the Travis County Flood Insurance Study (FEMA, 1997). The City of Austin provided a copy of the Corps of Engineers HEC-2 flood model for Onion Creek that was used to help prepare the FEMA study. This model had been previously developed in coordination with the Corps of Engineers. Cross-sections were taken directly from the model input, and rating curves were developed by running the model at different flows. Manning's n for the channel was estimated at 0.035.

Chemical fate coefficients required as input to REMM include lateral and longitudinal dispersion coefficients, and suspended solids concentrations. For the Colorado River, lateral dispersion ranged from 0.07 to 0.14 $m^2$/sec, and longitudinal dispersion ranged from 6 to 18 $m^2$/sec (low flow to flood flow). Suspended solids concentration was set at 100 mg/L. For Onion Creek, lateral dispersion was set at 0.024 $m^2$/sec, and longitudinal dispersion ranged from 0.2 to 15 $m^2$/sec. Suspended solids concentration was set at 10 mg/L.

Weather conditions were conservatively set at: air temperature = 40°F, water temperature = 50°F, wind speed = 10 mph. This simulates winter conditions when losses of volatile contaminants would be reduced.

## 4.3 Possible Pipeline Spill Scenarios

Three pipeline spill scenarios were evaluated for this study. These were small, medium, and large spills of 50, 500, and up to 5000 barrels (bbl), respectively. At the maximum pipeline flow of 225,000 bbl/day, the maximum possible spill at the Colorado River crossing is 85,100 gallons (approximately 2000 bbl) considering a complete pipeline rupture and total draindown of all product between high points in the line (see EA). Therefore, for the Colorado model, a maximum spill volume of 85,100 gallons was

used. At the Onion Creek crossing, the maximum possible spill is approximately 5000 bbl. Spills were modeled as an instantaneous discharge. It was assumed that 50 percent of the topwidth of the stream modeled would be "painted" by the spill. This affects the surface area of the spill, subsequent dispersion calculations, and evaporative losses.

# 5.0 MODEL RESULTS

This section presents the results of the modeling for the Colorado River and Onion Creek.

## 5.1 Colorado River

Figure 5-1 presents the results of the REMM modeling of the worst possible spill of gasoline on the Colorado River (85,100 gal., or approx. 2000 bbl) at low, median, and flood flows. Figure 5-2 presents the same information for a small (50-bbl) spill. The graphs show the simulated peak concentration of benzene as the spill travels downstream from the spill site. Except for the first few miles below the spill site, the downstream concentrations are relatively insensitive to flow. Following initial dilution, there is a logarithmic decay in benzene concentrations, and at the higher flows, the concentrations are fairly similar after about 25 miles. At low flow, the much longer travel time allows for greater evaporative losses, and the concentrations drop to near zero after about 25-35 miles. The low-flow condition is the only one in which the concentration dropped below the MCL of 5 ppb benzene for any size spill over the 118 miles modeled.

Figure 5-3 presents the results of the modeling of three different sized spills at low flow. Results are similar to the varied flow results discussed above, with little difference in concentrations between the three spill amounts after about 20 miles. The distance to reach the MCL of 5 ppb benzene ranged from 25 to 33 miles.

Figure 5-4 presents the results of a crude oil spill of similar size to the gasoline spill presented in Figure 5-1 at low and median flow. The model would not run at flood flow for this contaminant. These results show a much slower loss rate of crude oil as compared to gasoline. Even with an order-of-magnitude lower initial concentration of benzene in crude oil vs. gasoline, ultimate concentrations are not significantly different. In particular, the low flow case never drops below the MCL, and in fact, remains higher

than the median flow case for the entire reach modeled despite the much longer travel time. This is likely because of the lower volatility of crude oil.

Figure 5-5 presents the results of a worst-case MTBE spill (modeled as 12,765 gal. pure MTBE, which is 15% of 85,100 gal. gasoline). Results are similar to benzene in gasoline as discussed above. The minimum drinking water advisory level of 20 ppb is reached only at low flow after 34 miles.

Figure 5-6 shows the concentrations of MTBE over time at a fixed point downstream (Columbus, 92 miles) at median and flood flows. Note that at the higher flow, travel time is shorter and the concentration curve is higher and narrower. The peak concentration is about 5 mg/L approximately 96 hours after the spill, and the concentration is above 20 ppb for 15 hours. At the lower flow, even though there is less dilution, the increased travel time has resulted in more loss of contaminant through volatilization and more spreading out of the contaminant plume through dispersion. Peak concentration is about 3 mg/L approximately 135 hours after the spill, but the concentration is above 20 ppb for 20 hours. Other contaminants show similar trends.

## 5.2 Onion Creek

For Onion Creek, Figures 5-7 and 5-8 show benzene concentrations from a 50-bbl spill of gasoline and crude oil, respectively. Figure 5-9 shows MTBE concentrations from a 50-bbl gasoline spill (modeled as 315 gal. pure MTBE, which is 15% of 2100 gal. gasoline). The results are somewhat similar to the Colorado River. Concentrations drop off logarithmically and are relatively insensitive to flow after roughly 10-15 miles. Larger spill amounts show a similar trend. One difference with Onion Creek is that the benzene and MTBE concentrations never dropped below 5 ppb and 20 ppb, respectively, at any flow or spill amount. The main reason for this is the comparatively short distance on Onion Creek from the spill location to the mouth of the creek (the limit of modeling). A second reason is the smaller width of this creek as compared to the Colorado River. This results in smaller surface areas as the spill plume moves downstream and correspondingly reduced evaporative losses.

The results of modeling large spills at low flows on Onion Creek are suspect. An extremely low flow provides very little dilution for a spill of any size. Concentration calculations are not meaningful under these conditions. For example, at maximum capacity, the pipeline flow is projected to be 225,000 bbl/day. This is equivalent to about 15 cfs, which is 25 times the flow in the creek at the 7-day, 2-year low flow of 0.6 cfs. Furthermore, a spill that dominates the flow of the stream would be subject to other factors that are not considered by the model, such as interactions with stream banks and bottom sediments.

Figure 5-1 – Not available electronically

Figure 5-2 – Not available electronically

Figure 5-3 – Not available electronically

Figure 5-4 – Not available electronically

Figure 5-5 – Not available electronically

Figure 5-6 – Not available electronically

Figure 5-7 – Not available electronically

Figure 5-8 – Not available electronically

Figure 5-9 – Not available electronically

# 6.0 APPLICATION TO OTHER STREAMS

The REMM model has predicted impacts resulting from spills in the Colorado River and Onion Creek. There are other streams of interest that are crossed by the pipeline for which it is desirable to know the extent of potential impacts. Therefore, the results of the REMM models were subjected to a statistical analysis to develop a relationship that could be used to estimate impacts on other streams.

Multiple regression analyses were performed on the output from the Colorado River model, the Onion Creek model, and the combined data from the two models. The analyses yielded a useful equation based on the Colorado River model. The Onion Creek model yielded an equation that fit the data from Onion Creek, but the relatively short distance modeled produced unrealistic results when it was applied to other streams with longer distances and different hydraulic and hydrologic conditions. The combined data did not exhibit a relationship that could be described by an equation.

The regression equation from the Colorado River data used the following variables as input:

- Flow in cubic feet per second;
- Spill volume in gallons;
- Time of travel to a specified downstream point in hours; and
- Distance to the downstream point in river miles.

Using these variables, the equation calculates a concentration of benzene in mg/L (ppm) at the downstream point of interest. The equation is as follows:

$$\text{Log (Benzene conc.)} = 1.3103 - 0.000582(\text{Flow}) + 0.000065(\text{Spill}) + 0.0374(\text{Time}) - 0.3085(\text{Dist}) + 0.00872(\text{Dist})^2 - 0.0000143(\text{Dist})^3 - 5.228\text{E-}10(\text{Spill})^2 + 4.453\text{E-}8(\text{Flow})^2 + 0.0000675(\text{Dist})(\text{Time}) + 0.00021(\text{Dist})(\text{Flow}) - 0.0000618(\text{Time})(\text{Flow}) - 0.000115(\text{Dist})^2(\text{Time}) - 0.00000552(\text{Dist})^2(\text{Flow}) + 2.14\text{E-}7(\text{Dist})^3(\text{Time}) - 1.906\text{E-}10(\text{Dist})^3(\text{Flow}) + 6.064\text{E-}9(\text{Time})(\text{Flow})^2 - 1.838\text{E-}8(\text{Dist})(\text{Flow})^2 + 4.847\text{E-}10(\text{Dist})^2(\text{Flow})^2 - 1.48\text{E-}7(\text{Time})(\text{Flow})(\text{Dist}) + 8.104\text{E-}8(\text{Flow})(\text{Time})(\text{Dist})^2 - 2.312\text{E-}11(\text{Flow})(\text{Time})(\text{Dist})^3 - 1.141\text{E-}11(\text{Time})(\text{Dist})(\text{Flow})^2 - 6.697\text{E-}12(\text{Time})(\text{Flow})^2(\text{Dist})^2$$

The adjusted R-square value for this equation was 0.9992. Whereas this generally indicates that the regression equation provides a good fit to the data, it should be pointed out that there was some inter-correlation between the variables that artificially increased the R-square value. Moreover, the fit to the data was not equally good over the entire range of conditions. For example, for short distances, the regression equation tends to underestimate concentrations relative to the REMM model. In addition, although this equation generally fit the data well for the Colorado River and for the conditions under which the model was run, it may not be as applicable to other streams or conditions which fall outside of the range of data modeled, such as lower flows, higher or lower velocities, larger spills, or longer travel times or distances. In summary, the equation appears to be a reasonable predictor of concentrations, but it must be used carefully, with recognition that it is merely an estimation tool and not a verified model.

To apply the equation to other streams, values are required for the four input variables. Flow, spill volume, and distance can be selected as desired, but time of travel must be calculated. Travel time was estimated using a methodology described in a USGS Water Resources Investigation Report (Jobson, 1996). The methodology uses a regression equation relating travel time to drainage area, mean annual flow, instantaneous flow, and channel slope. Drainage areas and other data on the streams of interest at the pipeline crossing locations were obtained from the EA. Mean annual and other flows were estimated using drainage area ratios from nearby USGS gaging stations. The

maximum spill volume was limited to 2000 bbl to keep it within the range of spills represented by the Colorado River data.

The other streams evaluated were as follows:

- Llano River
- James River
- Pedernales River
- Barton Creek
- Cedar Creek
- Alum Creek
- Pin Oak Creek
- Rabbs Creek
- Cummins Creek

The north and south valleys of the San Saba River and Sandy Creek (Gillespie County) were not evaluated, even though they are tributaries of the Colorado River crossed by the pipeline. These streams are crossed near their headwaters. Travel distance along the San Saba River to its mouth is greater than 150 miles. Flows on theses streams would be too small to perform a reasonable analysis of impacts using the regression equation.

The results of the analysis are presented in Table 6-1. The stream mileages in the table are estimated distances to reach 5 ppb benzene under the stated conditions of flow and spill volume. Actual stream mileage from the pipeline crossing point to the mouth of each stream is listed for reference, but this was not considered in the analysis. The range of estimated impacts was 19 – 33 miles under low flow, 25 – 48 miles under average flow (excluding REMM results for Colorado River of >100 miles), and 46 – >100 miles under flood flow conditions. For smaller streams, no low-flow calculations were performed,

Table 6-1 – Not available electronically

because the estimated 7-day, 2-year low flow is at or near zero. For several streams, flood-flow calculations did not yield meaningful results.

# 7.0 CONCLUSIONS

The U.S. Army Corps of Engineers REMM model was applied to the Longhorn Pipeline System at major stream crossings within the Colorado River Basin to determine potential impacts from spills of petroleum products. The Colorado River and Onion Creek were modeled directly using REMM. Impacts were estimated to nine other streams using a regression equation developed from the results of the Colorado River model.

Several general conclusions were reached regarding the possible impact of a pipeline spill to these surface waters:

- Significant impacts (benzene concentrations >5 ppb or MTBE concentrations >20 ppb) to the Colorado River would likely occur for more than 100 miles downstream of the spill, except at low flow.

- Under low flow, significant impacts to the Colorado River would occur for 25 – 33 miles downstream.

- The duration of impacts (time for complete plume passage) at a downstream location is primarily dependent on flow and distance downstream. At Columbus, 92 miles downstream of the Colorado River crossing, the leading edge of the plume would arrive roughly 100 hours following a spill at average flows, and the trailing edge would pass after approximately 15 – 20 hours.

- Significant impacts to Onion Creek are projected to occur all the way to the mouth, or 26 miles from the modeled spill location, under all flow and spill conditions. Model results at very low flows may not be accurate, and actual impacts may not be as far as projected under those conditions.

- Impacts to other streams are estimated to be from approximately 20 to over 100 miles, with longer distances associated with larger spill volumes and higher flows. These are rough estimates made using a regression relationship based on the Colorado River model results.

- Impacts from a similar-sized crude oil spill would be over a greater distance than a gasoline spill, primarily because of the lower volatility of crude oil.

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